Appendix B

Site Background and Physical Characteristics of the INEEL

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Site Background and Physical Characteristics of the INEEL

B-1. SITE BACKGROUND AND HISTORY

The Idaho National Engineering and Environmental Laboratory (INEEL) is a government-owned reservation managed by the U.S. Department of Energy (DOE). The eastern boundary of the INEEL is located 51 km (32 mi) west of Idaho Falls, Idaho (see Figure B-1). The INEEL Site occupies approximately 2,305 km^2 (890 mi^2) of the northern portion of the Eastern Snake River Plain (ESRP). The INEEL Site is nearly 63 km (39 mi) long from north to south and about 58 km (36 mi) in its broadest southern portion. The INEEL includes portions of Bingham, Bonneville, Butte, Clark, and Jefferson counties (DOE-ID 1997). Figure B-2 is a map of the INEEL and identifies some of its major facilities and the general area of the Waste Area Groups (WAGs) 6 and 10 sites.

During World War II, the U.S. Navy and Army used a large portion of the area that is now the INEEL as a gunnery and bombing range. In 1949, the U.S. Atomic Energy Commission established the National Reactor Testing Station (NRTS) on the Site. The NRTS was renamed twice: first as the Idaho National Engineering Laboratory (INEL) in 1974, and then as the INEEL in 1997 (DOE-ID 1997). The U.S. Bureau of Land Management (BLM) controlled the land, primarily as rangeland, before the NRTS was established. Public land orders in 1946, 1949, and 1950 withdrew the land from the public domain. Since 1957, approximately 699 km^2 (270 mi^2) of the INEEL, excluded from public access, has been relatively undisturbed. Currently, between 1,217 and 1,425 km^2 (470 and 550 mi^2) are open to grazing through BLM administered permits. The DOE established the INEEL as a National Environmental Research Park in 1975. This is one of only two such parks in the United States that allows comparative ecological studies in sagebrush-steppe ecosystems (DOE-ID 1997).

July 17, 1999, the Department of Energy, U.S. Fish and Wildlife Service, the Idaho Fish and Game Department, and the Bureau of Land Management created the Sagebrush Steppe Ecosystem Reserve at the INEEL. This reserve will conserve 74,000 acres of unique habitat on the northwest portion of the INEEL. The INEEL contains some of the last sagebrush steppe ecosystem in the United States. This action recognized that the INEEL has been a largely protected and secure facility for 50 years and that portions are valuable for maintaining this endangered ecosystem.

B-2. PHYSIOGRAPHY

The Snake River Plain (SRP) is the largest continuous physiographic feature in southern Idaho (Figure B-3). This large topographic depression extends from the Oregon border across southern Idaho to Yellowstone National Park and northwestern Wyoming.

The SRP slopes upward from an elevation of about 750 m (2,500 ft) at the Oregon border to more than 1,500 m (5,000 ft) at Ashton northeast of the INEEL. The East and Middle buttes have elevations of 2,003 and 1,949 m (6,572 and 6,394 ft), respectively. The SRP is composed of two structurally dissimilar segments, with the division occurring between the towns of Bliss and Twin Falls, Idaho. West of Twin Falls, the Snake River has cut a valley through tertiary basin fill sediments and interbedded volcanic rocks. The stream drainage is well developed, except in a few areas covered by recent thin basalt flows. East of Bliss, Idaho, the complexion of the plain changes as the Snake River locally carves a vertical-walled canyon through thick sequences of quaternary basalt with few interbedded sedimentary deposits.

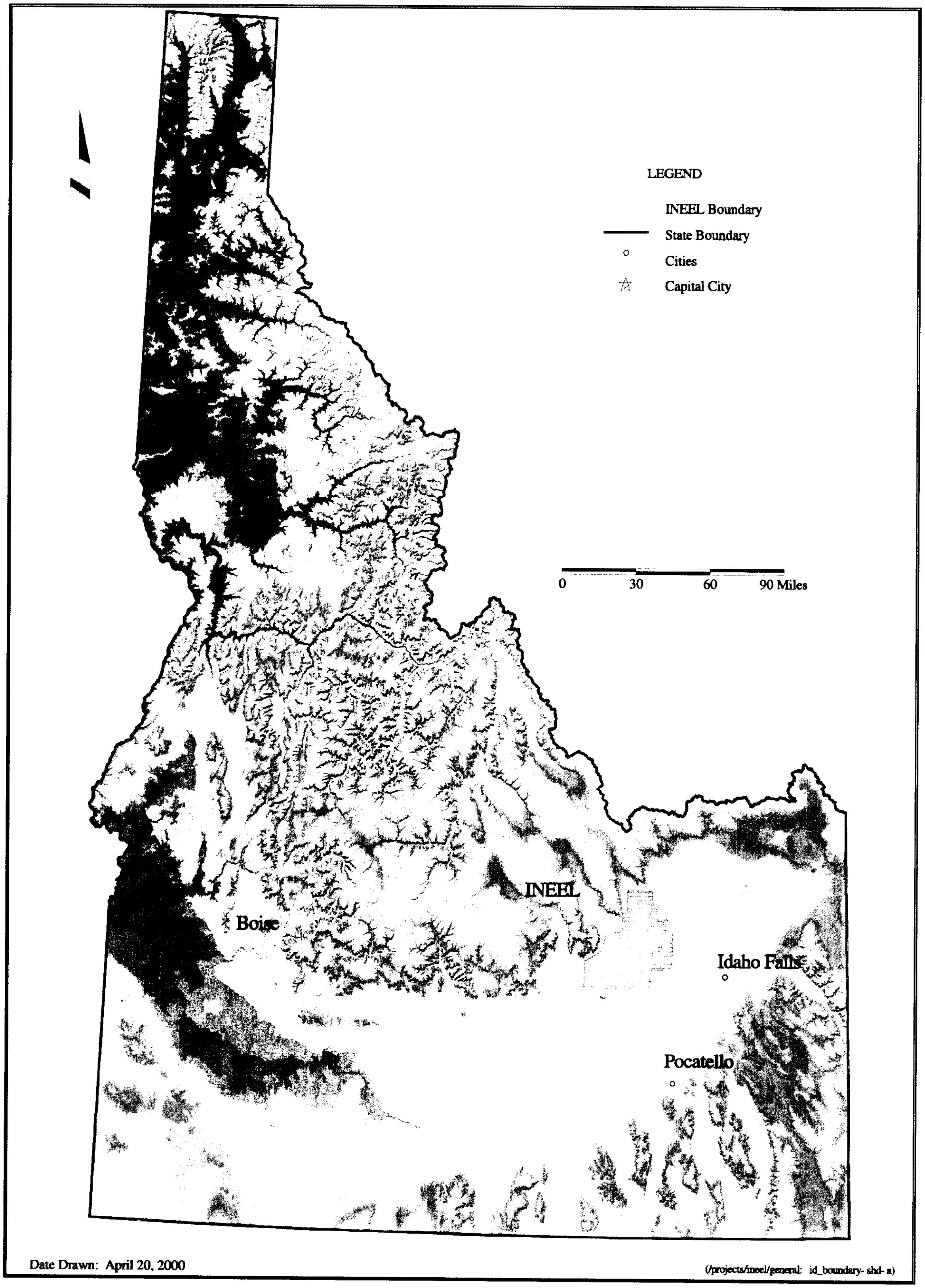

Figure B-1. The INEEL Site vicinity map.

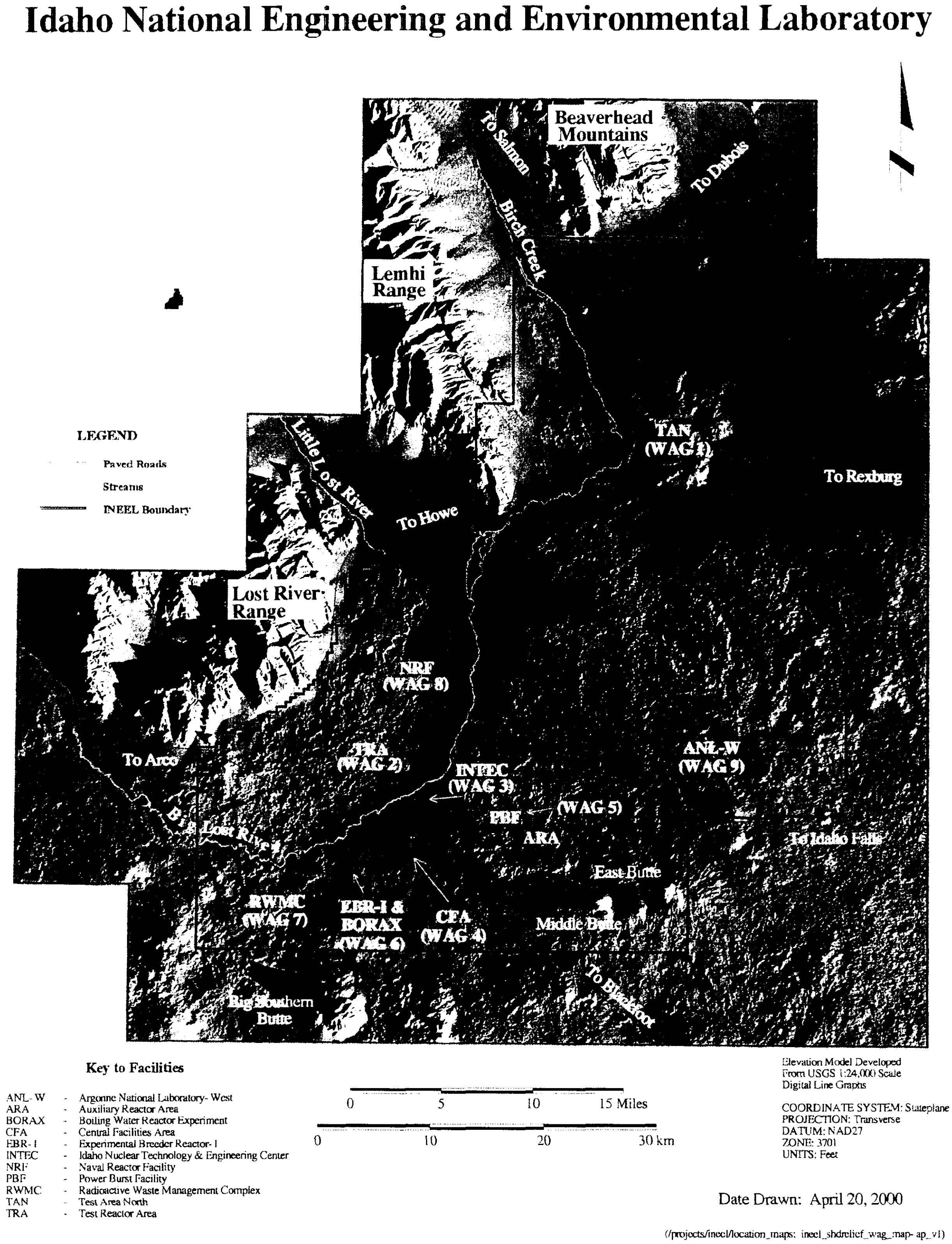

Figure B-2. Location of INEEL facilities and general area of WAGs 6 and 10.

The INEEL is located on the northern edge of the Eastern Snake River Plain (ESRP), a northeastern-trending basin, 80 to 110 km (50 to 70 mi) wide, extending from the vicinity of Bliss on the southwest to the Yellowstone Plateau on the northeast (Figure B-3). Three mountain ranges end at the northern and northwestern boundaries of the INEEL: (1) the Lost River Range, (2) the Lemhi Range, and (3) the Beaverhead Mountains of the Bitterroot Range (Figure B-1). Between the ranges and the relatively flat plain is a relief of 1,207 to 1,408 m (3,960 to 4,620 ft) (Hull 1989). Saddle Mountain, near the southern end of the Lemhi Range, reaches an altitude of 3,295 m (10,810 ft) and is the highest point in the immediate INEEL area.

The portion of the SRP occupied by the INEEL may be divided into three minor physiographic provinces. The first province is a central trough, often referred to as the Pioneer Basin, that extends to the northeast through the INEEL. Two flanking slopes descend to the trough, one from the mountains to the northwest and the other from a broad ridge on the plain to the southeast. The slopes on the northwestern flank of the trough are mainly alluvial fans originating from sediments of Birch Creek and the Little Lost River. Also forming these gentle slopes are basalt flows that have spread onto the plain. The land forms on the southeast flank of the trough are formed by basalt flows, which spread from a volcanic zone that extends northeastward from Cedar Butte. The lavas that erupted along this zone built up a broad topographic swell directing the Snake River to its current course along the southern and southeastern edges of the plain (Figure B-4). This topographic swell effectively separates the drainage of mountain ranges northwest of the INEEL from the Snake River.

The Pioneer Basin of the INEEL broadens to the northeast and joins the extensive Mud Lake Basin. The Big and Little Lost Rivers and Birch Creek drain into this basin from valleys between the mountains to the north and west. The intermittently flowing waters of the Big Lost River have formed a flood plain in this trough, consisting primarily of fine sands, silt, and clay. Streams flow to the Big Lost River and Birch Creek sinks, a system of playa depressions in the west-central portion of the INEEL, southeast of the town of Howe, Idaho. The sinks area covers several hundred acres and is flat, consisting of significant thicknesses of fluvial and lacustrine (lake) sediments.

B-3. METEOROLOGY AND CLIMATOLOGY

Atmospheric transport of contaminants is controlled by the following physical parameters: particle size, climate, local meteorology, local topography and large structures or buildings on-Site, and contaminant source strength. This subsection describes the aspects of the natural phenomena and physical parameters that are necessary to evaluate environmental and human health impacts from atmospheric transport of contaminants from WAGs 6 and 10 sites.

The National Oceanic and Atmospheric Administration (NOAA) and its predecessor have operated meteorological observation programs at the INEEL since 1949. The NOAA staff makes a full range of hourly and daily meteorological observations. As of June 15, 2000, 33 meteorological observation (Mesonet) stations were in operation at or surrounding the INEEL. Four of these are operated in cooperation with the State of Idaho INEEL Oversight Program and the Shoshone-Bannock tribes. Real time data from these stations are available on the NOAA website (http://www.noaa.inel.gov/windvector/) and are updated every five minutes. Three stations are equipped to measure wind speed and air temperature at multiple levels up to 76 m (250 ft) above the ground. These three towers are located at Central Facilities Area (CFA), Argonne National Laboratory-West (ANL-W), and the Test Reactor Area (TRA). Atmospheric humidity is recorded at CFA and ANL-W. The precipitation and air temperature at the 1.5-m (5-ft) level are recorded at CFA.

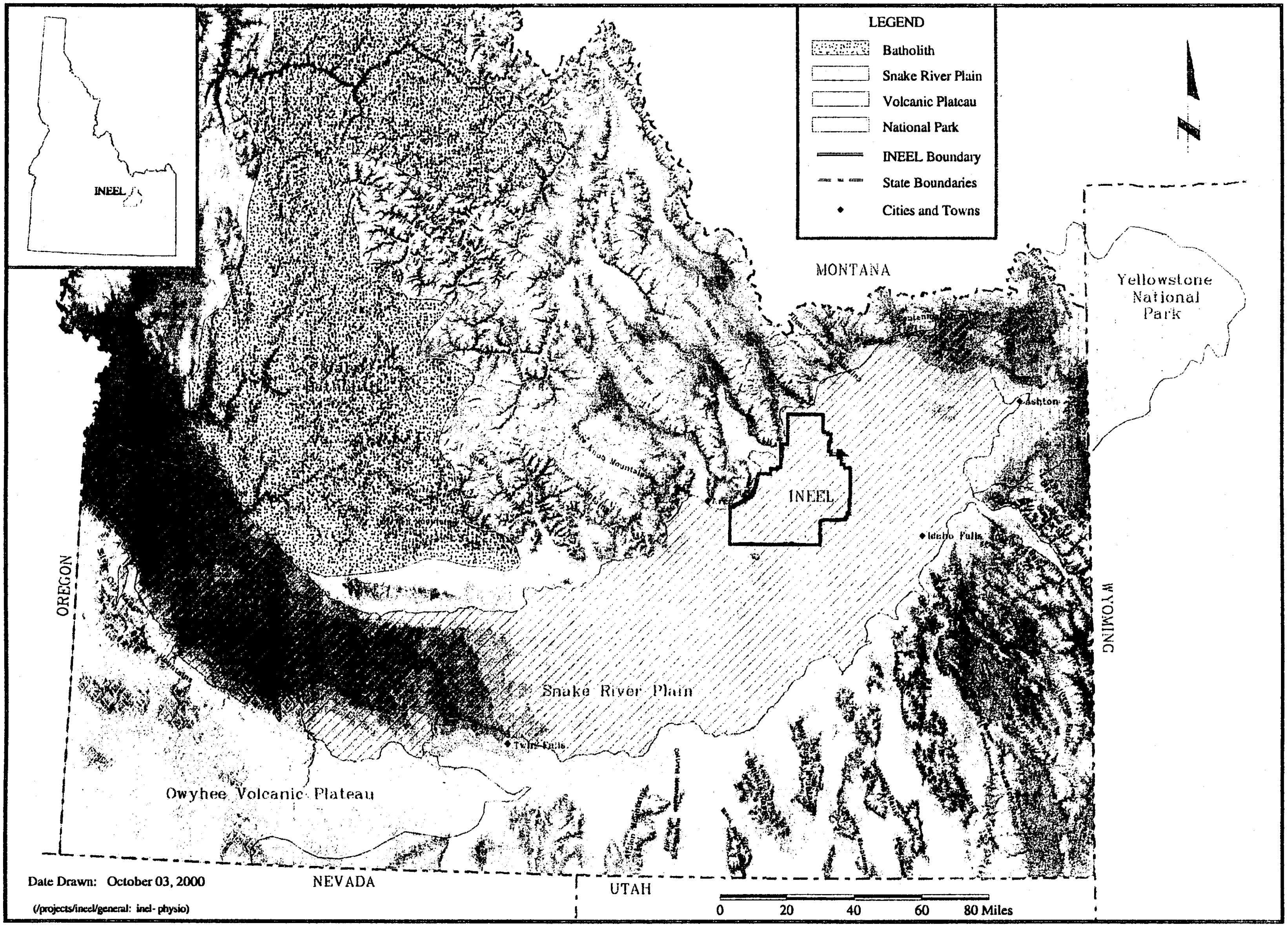

Figure B-3. Physiographic and geologic features of the INEEL area.

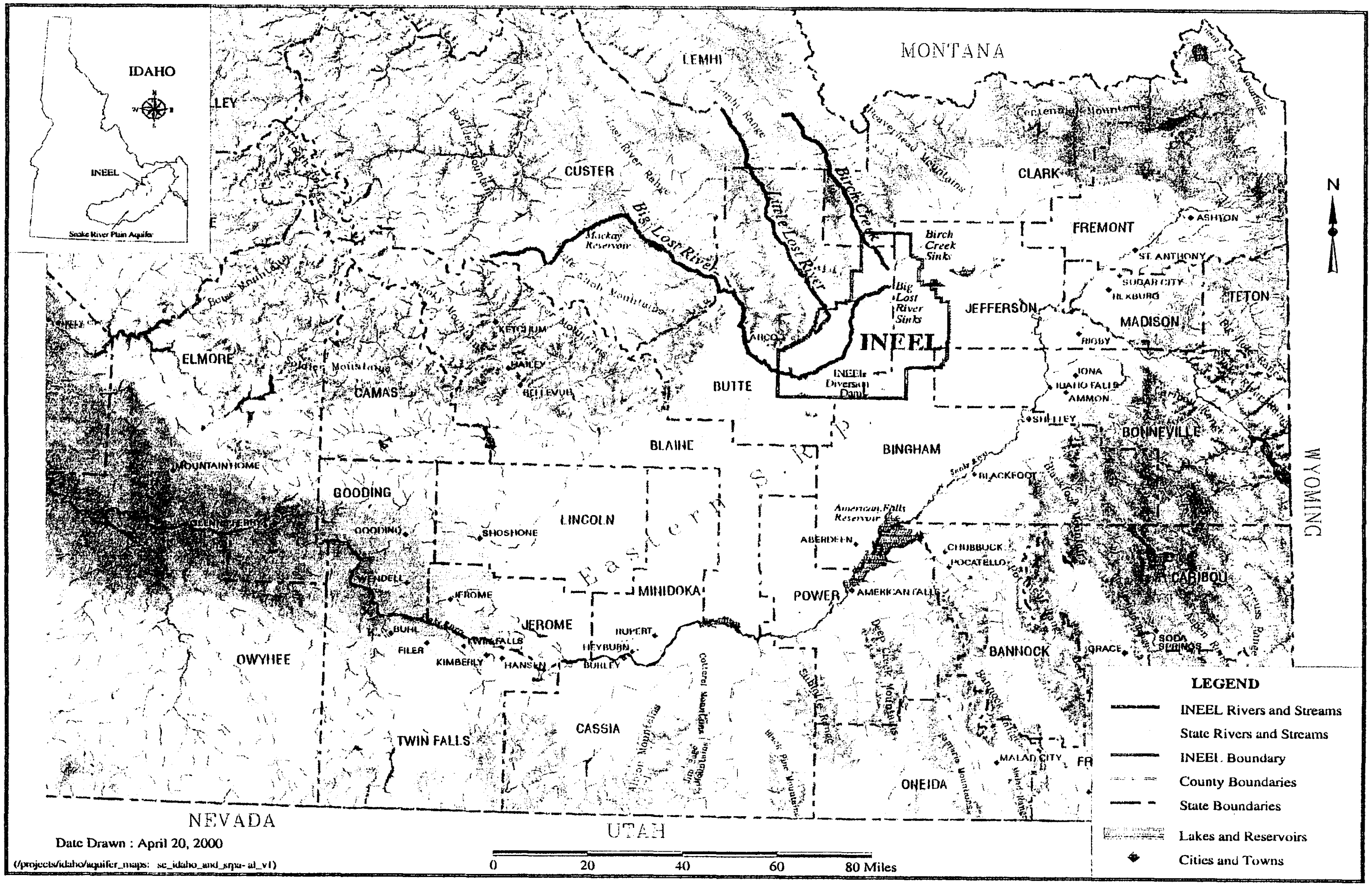

Figure B-4. Locations of the Big Lost River, Little Lost River, and Birch Creek.

A station at TRA has been operational since 1971 and is used to measure windspeed and direction 15 m (50 ft) above the ground. A primary observation station, Grid 3 (GRD3), is located approximately 5 km (3 mi) east-northeast of the TRA station. The Grid 3 station was put into service in 1957 and is used to measure windspeed and direction at multiple levels. Since 1979, air temperature at multiple levels also has been recorded at the station. The longest and most complete record of meteorological observations exists for the CFA station. Most of the information presented in this section is summarized from a 1989 climatography report map of the INEEL (Clawson et al. 1989), which compiled weather recordings for the period from 1949 to 1988. Air mass characteristics, proximity to moisture sources, the angle of solar incidence, temperature, and other effects caused by latitude differences would be expected to be similar for all locations at the INEEL. Therefore, extrapolation of meteorological data from CFA to other locations at the INEEL is possible (Bowman et al. 1984).

The climate at the INEEL is influenced by the regional topography and upper-level wind patterns over North America. The Rocky Mountains and the SRP help to create a semiarid climate with an average summer-daytime maximum temperature of 28°C (83°F) and an average winter-daytime maximum temperature of -0.5°C (31°F). Infrequent cloud cover over the region allows intense solar heating of the ground surface during the day, and the low absolute humidity allows significant radiant cooling at night. These factors create large temperature fluctuations near the ground (Bowman et al. 1984). During a 22-year period of meteorological records (1954 through 1976), temperature extremes at the INEEL have varied from a low of -41°C (-43°F) in January to a high of 39°C (103°F) in July (Clawson et al. 1989).

The average relative humidity at the INEEL ranges from a monthly average minimum of 15% during August to a monthly average maximum of 81% during February and December. The relative humidity is related to diurnal temperature fluctuations. Relative humidity generally reaches a maximum just before sunrise (the time of minimum daily temperature) and a minimum in the late afternoon (time of maximum daily temperature) (Van Deusen and Trout 1990).

The average annual precipitation at the INEEL is 21.5 cm (8.5 in.). The months with the highest precipitation rates are May and June, and the month with the lowest is July. Snowfall at the INEEL ranges from a low of about 30.5 cm (12 in.) per year to a high of about 102 cm (40 in.) per year, with an annual average of 66 cm (26 in.). Normal snowfall occurs from November through April, though occasional snowstorms occur in May, June, and October (Van Deusen and Trout 1990).

A statistical analysis of precipitation data from CFA for the period from 1950 through 1990 was made to determine estimates for the 25- and 100-year maximum 24-hour precipitation amounts and 25-and 100-year maximum snow depths (Sagendorf 1991). Results from this study indicate 3.43 cm (1.35 in.) of precipitation for a 25-year, 24-hour storm event, and 4.1 cm (1.6 in.) of precipitation for a 100-year, 24-hour storm event. The 25-year maximum snow depth is 57.4 cm (22.6 in.), and the 100-year maximum snow depth is 77.8 cm (30.6 in.) (Sagendorf 1991).

Potential annual evaporation from saturated ground surface at the INEEL is approximately 91 cm (36 in.). Eighty percent of this evaporation occurs between May and October. During the warmest month (July), the potential daily evaporation rate is approximately 0.63 cm/day (0.25 in./day). During the coldest months (December through February), evaporation is low and may be insignificant. Transpiration by native vegetation on the INEEL approaches the total annual precipitation input. Potential evapotranspiration is at least three times greater than actual evapotranspiration (Kaminsky et al. 1993).

The local topography, mountain ranges, and large-scale weather systems influence the local meteorology. The orientation of the bordering mountain ranges and the general northeast-southwest orientation of the ESRP play an important role in determining the wind regime. Wind roses for each

INEEL meteorological station represent hourly averaged historical surface wind data. The percentage of time that the wind blows from each direction and the speed at which it blows are recorded on the wind roses. Wind speed and direction are always recorded as the direction from which the wind is blowing. The southwest wind direction predominates across the INEEL, and the northeast flow direction is the second most frequent pattern. This is a result of the southwest-northeast orientation of the ESRP when convective heating couples the surface winds with the persistent westerly winds aloft. Although the INEEL is in the belt of prevailing westerly winds aloft, the surface winds (from the ground surface up to approximately 5,000 ft above the ground surface) are most frequently west-southwest or southwest as they are channeled or redirected along the northeast-southwest trending ESRP. When the prevailing westerlies at the gradient level (approximately 10,000 to 12,000 ft above ground) are strong, the surface winds channeled across the ESRP between the mountains become very strong. Some of the highest windspeeds at the INEEL have been observed under these meteorological conditions. The greatest frequency of high winds occurs in the spring (Clawson et al. 1989).

Local mountain and valley features exhibit a strong influence on the wind flow under other meteorological conditions as well. When the winds above the level of the mountains are strong and from a direction a little north of west, channeling in the ESRP usually continues to produce southwesterly winds over most of the INEEL. Prefrontal winds are also invariably southwesterly. However, at the mouth of Birch Creek the northwest to southeast orientation of this valley channels strong north-northwest winds (Clawson et al. 1989).

The southwest wind occurs primarily during the daytime when the air along the mountain slopes is heated more rapidly than the air at the same elevation over the valley. The air rises along the slopes as it becomes less dense. This up-slope wind, in turn, contributes to the production of the most frequent wind pattern for the INEEL, which is an up-valley, or southwest, wind (Clawson et al. 1989).

The opposite happens at night when drainage winds reverse the overall wind flow over the INEEL, creating the second most frequent wind pattern. On clear or partly cloudy nights with only high thin clouds, the Snake River Plain valley experiences a rapid surface radiational cooling. This results in a simultaneous cooling of the air near the surface, which in turn causes the air to become stable and less turbulent. However, air along the slopes of the mountains cools at a faster rate than the air at the same elevation located aloft over the Snake River Plain valley. Consequently, it becomes denser and flows or sinks toward the valley floor forming a down-slope wind. When this wind reaches the valley, it still flows toward lower elevations and becomes a down-valley wind. The main nocturnal down-valley flow is the second most frequent wind observed over the INEEL and flows primarily out of the north-northeast (Clawson et al. 1989). Pressure gradient forces related to passing large-scale weather systems, as well as local storms, affect the winds across the INEEL. These storms alter the local flow regime such that winds from any direction can be observed. The frequency of occurrence, however, of these types of wind flow patterns is very low (Clawson et al. 1989).

Wind gusts at the INEEL may be a result of either pressure gradients from large-scale systems, or the result of local thunderstorms. Most gusts from pressure gradients are channeled from the southwest. However, gusts from thunderstorms can be expected from any direction since they may form in any location and move in any direction (Clawson et al. 1989).

April is the month with the highest average monthly windspeed near surface (6 m [20 ft]) height, which for CFA is 15.3 km/h (9.3 mph). December is the month with the lowest average monthly windspeed (Clawson et al. 1989).

The INEEL is subject to severe weather. Thunderstorms with tornadoes are observed mostly during the spring and summer, but the tornado risk probability at the INEEL is about 7.8×10^{-5} per year

(Bowman et al. 1984). An average of two to three thunderstorms a month occurs from June through August. Thunderstorms accompanied by strong gusty winds may produce local dust storms. Occasionally, a single thunderstorm will exceed the average monthly total precipitation (Bowman et al. 1984). Precipitation from thunderstorms at the INEEL is generally light.

Dust devils, common in the region, can entrain dust and pebbles and transport them over short distances. They usually occur on warm sunny days with little or no wind. The dust cloud may be several tens of meters (yards) in diameter and extend several hundreds of meters (hundred yards) into the air (Bowman et al. 1984).

NOAA assembled an extensive record of upper air observations from routine pibal (pilot balloon) observations from 1950 to 1965. During those years, a pibal was released every morning at CFA in order to obtain the wind speed and direction at selected levels above the surface. These balloons were tracked up to heights of 14,000 ft above mean sea level. A wind rose for every 1,000-ft elevation is shown on Figure B-5. These wind roses illustrate variation in wind speed and direction with height above the INEEL. The frequency of northeast winds decreases and the frequency of west-southwest winds increases with height. The presence of the prevailing westerlies at and above the general mountaintops (10,000 ft above mean sea level) is also apparent. This wind, which is undisturbed by the mountains, and occurs above them, is termed the gradient wind (Clawson et al. 1989).

The vertical temperature and humidity profiles in the atmosphere determine the atmospheric stability. Low levels of turbulence and less vertical mixing characterize stable atmospheres. This results in higher ground-level concentrations of emitted contaminants. The stability parameters at the INEEL range from stable to very unstable. Stable conditions occur mostly at night during strong radiant cooling. Unstable conditions occur during the day during periods of strong solar heating of the surface layer, or whenever a large-scale disturbance passes over the region (Bowman et al. 1984).

B-4. GEOLOGY

The assessment of contaminant extent, transport, and pathways, evaluation of risk, and development of remedial action alternatives depend in large part on the geologic materials of a site and on the geologic phenomena to which each site may be subjected. The information presented in this section furnishes the geologic context for the surface and groundwater hydrology sections. Information contained in the regional and local geology sections was extracted from Holdren et al. (1997).

B-4.1 Regional Geology

To set the stage for the following discussions, a general chronology of geologic events that have affected the INEEL area is presented here. During Paleozoic and early Mesozoic time (150 to 600 million years ago) most of the area now occupied by Idaho lay off the west coast of the North American continent and was the site of deposition of thick deposits of limestones, sandstones, and shales. In late Mesozoic and early Tertiary times (50 to 100 million years ago), those sedimentary rocks were compressed from the west to form a broad area of crumpled and thrust-faulted rocks, called the Overthrust Belt, which extends from northern Idaho, through southeastern Idaho and western Wyoming, to central Utah. By middle Tertiary time (20 to 30 million years ago), most of the present western United States was elevated above sea level and began to experience extension in a generally east-west direction. The extensional

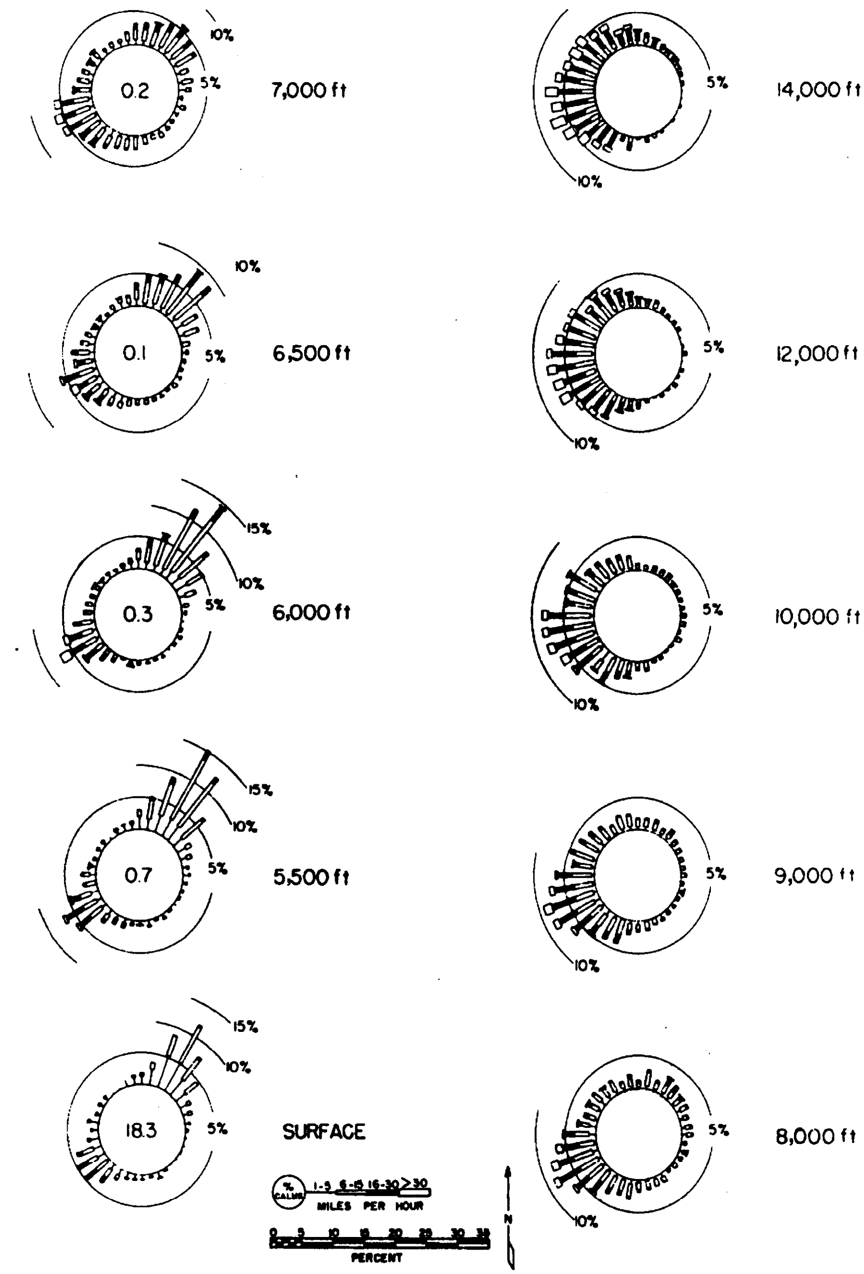

Figure B-5. Wind patterns from the surface to 14,000 ft above the INEEL (from Clawson et al. 1989).

deformation produced the Basin and Range province, a broad zone of generally north-trending faults and associated mountain ranges that covers most of Nevada, and parts of Idaho, Utah, California, and Arizona.

The Yellowstone hot spot, a rising plume of hot material in the earth's mantle, first impinged on the base of the lithosphere about 17 million years ago in north-central Nevada (Figure B-6). The southwestward migration of the North American lithospheric plate across the stationary hot spot has produced most of the observed characteristics of the Snake River Plain. Today the hot spot lies beneath the Yellowstone Plateau and is responsible for the spectacular geothermal features and large thickness of volcanic rocks of which the area is composed. The hot spot progresses across this region at a constant rate emplacing volcanic rhyolite along the track of the hot spot. Rhyolitic volcanic rocks of 17-million-year age mark the location of the first appearance of the hot spot in north-central Nevada. Progressively younger rhyolites occur with distance towards Yellowstone, and rhyolites of 4.3- to 7-million-year age occur beneath the ESRP in the area of INEEL. Basaltic volcanism commenced after passage of the hot spot from beneath the ESRP about 4.3 million years ago, and has continued until today, producing the extensive lava fields characteristic of the basin.

The recent geologic history (the last 5 to 10 million years) of the ESRP has profound impact on the nature of the geologic materials on which the facilities may be located and on the geologic processes or phenomena that may affect these sites. Therefore, the discussion of regional geology concentrates on the recent past and on the contemporary geologic processes operating in the area of the INEEL.

B-4.1.1 Eastern Snake River Plain Basin

The subsurface materials underlying the INEEL are the unique result of geologic processes that led to the accumulation of materials. The interaction of the Yellowstone hot spot (a rising plume of hot mantle material beneath the continent) with the crust is responsible for the unique character of the plain. Passage of the continent southwestward over the stationary hot spot created an elongated volcanic province within the faulted, mountainous region of the northern Basin and Range province and the northern Rocky Mountains (Figure B-6) (Pierce and Morgan 1992; Smith and Braile 1994). As the INEEL area of the ESRP passed over the hot spot about 4.3 to 7 million years ago, the crust was heated and uplifted, and voluminous volcanism, characteristic of that seen at Yellowstone National Park today, created a sequence of rhyolitic lava flows and ash flows. Deep drilling at the INEEL indicates that the thickness of this sequence is as much as several kilometers (Hackett and Smith 1992). The ESRP began to subside after it moved off of the hot spot about 4.3 million years ago. The increased load of dense magmatic rocks emplaced in the middle crust and the contraction of crustal rocks during cooling caused a total subsidence of about 2 km (1.2 mi). The northeast-elongate subsiding basin extends from the Twin Falls area on the southwest to the Yellowstone Plateau on the northeast, a distance of about 322 km (200 mi). The basin then filled with basalt lava flows that were erupted from numerous volcanic vents throughout the plain and with unconsolidated sediments deposited by water and wind. This sequence of basalts and sediments covers the older rhyolitic volcanic rocks to depths of about 1 km (0.6 mi) as revealed by several deep drill holes in the INEEL area. The continuing subsidence coupled with the eruption of basalt lava flows and accumulation of sediments produces the low relief and low elevation characteristic of the surface of the plain. Tectonic processes, including uplift of the Yellowstone Plateau above the mantle hot spot and normal faulting in the northern Basin and Range Province, maintain the high elevations and mountainous character of the region surrounding the plain.

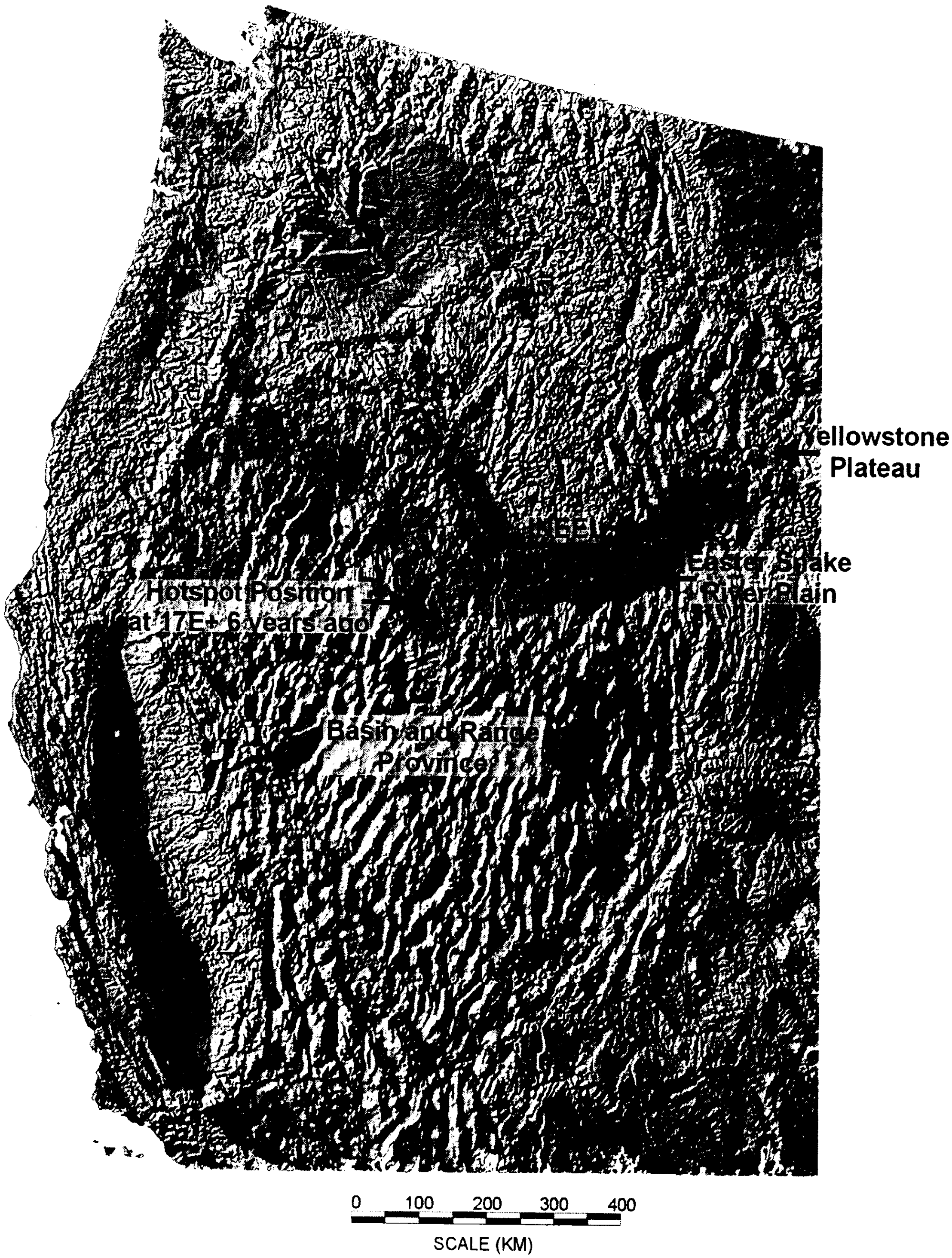

Figure B-6. Digital shaded relief topographic map of the Western United States.